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# Effects of Polybrominated Biphenyl on Milk Production, Reproduction, and Health Problems in Holstein Cows

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**PBB found in relatively low levels among animals present on a cross-section of Michigan farms during the time PBB was inadvertantly added to dairy feeds had no effect upon these animals' milk production, body weight, weight gain, breeding and reproductive performance, incidence of commonly experienced health problems, calving rate, and the health of their calves. No significant differences in these vital areas could be seen between Michigan animals exposed to PBB and equivalent Wisconsin animals which had not been exposed to PBB when both groups were subjected to equivalent management practices. No pattern of gross or histopathological lesions was seen upon necropsy between test animals and control animals.**

In May 1973, Farm Bureau Services received 80 50-lb bags of a dairy feed additive invoiced as magnesium oxide at its feed plant in Battle Creek, Michigan. Subsequent events have indicated that an unknown number of 50-lb bags of a flame retardant known as polybrominated biphenyl (PBB) were accidentally commingled with the May, 1973 magnesium oxide shipment. As a result, some dairy feeds made after May 1973 and into which bagged magnesium oxide was added directly contained small quantities of PBB. Other feeds which were mixed after the feeds into which PBB was mistakenly added, or which were stored in bins where feeds containing PBB were stored also contained minute quantities of the chemical.

The chemical was identified in late April of 1974. Since then many Michigan dairy producers whose animals consumed various quantities of PBB have claimed that PBB caused a variety of clinical symptoms, including: decreased milk production, loss of body weight, decreased appetite followed by an increased appetite, increased incidence of mastitis, increased breeding problems, abnormal hoof growth, hyperkeratosis and other skin problems, abnormal tooth wear, stunted or deformed calves, increased calf mortality, and decreased resistance to normal infections. Other farmers whose animals consumed quantities of PBB equivalent to, or in some cases higher than, the amounts consumed by animals claimed to have been adversely affected by PBB have reported that their animals did not exhibit any of the clinical symptoms commonly attributed to PBB.

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Controlled PBB feeding studies conducted at Ohio State University, USDA-Beltsville, Maryland, and Industrial Bio-Test Laboratories in Northbrook, Illinois, have shown that dairy animals did not exhibit the clinical symptoms commonly attributed to PBB until they consumed comparatively massive doses of PBB.

The precise amount of PBB fed in controlled feeding studies may not duplicate the time and dose parameters of exposures to PBB encountered at the farm level. Therefore, Farm Bureau Services and its supplier of magnesium oxide, the Michigan Chemical Corporation (now Velsicol Chemical Corporation), commissioned a 2-year study to evaluate the effects of PBB on milk production, reproduction, offspring performance, and overall health problems under dairy farm conditions.

## Procedures

Beginning in July 1976, 46 adult Holstein cows from six herds across Michigan which had been exposed to PBB were purchased as test animals. Each Michigan herd had been and was on a Dairy Herd Improvement Association, Inc. (DHIA) testing program. The test animals were selected on the basis of

**Table 1. Feed consumption—adult cows.**

| Ingredients | Feed consumption, lb/cow/day | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | High with magnets[a] | | High | | Low | | Dry | |
| | As fed | DM[b] | As fed | DM | As fed | DM | As fed | DM |
| Corn silage | 34.2 | 12.4 | 34.2 | 12.4 | 32.7 | 11.9 | 33.4 | 12.1 |
| Alfalfa haylage | 13.2 | 5.5 | 13.2 | 5.5 | 10.8 | 4.5 | 10.6 | 4.8 |
| Alfalfa hay | 13.6 | 12.4 | 13.6 | 12.4 | 14.0 | 12.8 | 11.9 | 10.9 |
| Grain[c] | 33.8 | 30.4 | 18.3 | 16.5 | 10.6 | 9.5 | 1.0 | .9 |
| Total | 94.8 | 60.7 | 79.3 | 46.8 | 68.1 | 38.7 | 56.9 | 28.7 |

[a] Cows received and lost neck chain magnets when their milk production exceeded or dropped below 55 lb of milk per day.
[b] Dry matter.
[c] The grain consisted of a 14% and 16% commercial pellet for producing cows and a 34% pellet for dry cows containing grain products, plant protein products, processed grain by-products, forage products, cane molasses, pellet binders, animal fat, vitamins, and minerals.

PBB tissue levels, previous milk production, health problems and reproductive problems.

Beginning in August 1976, 40 adult Holstein cows from five unexposed herds in different areas of Wisconsin were purchased as control animals and placed with the Michigan animals to form one herd. The control animals were selected in an effort to match the animals selected from Michigan in milk production, stage of lactation, housing, and management conditions. All animals, test and control, were examined by a licensed veterinarian for any permanent anatomical and physiological defects, leptospirosis, brucellosis, and tuberculosis. Blood samples were collected from the animals at or before the time(s) they joined the experimental herd. Blood samples were collected from 41 animals selected at random in April, 1977. Fat tissue samples were collected from each animal at or before the time she entered the experimental herd and were analyzed for the presence of PBB. The average PBB tissue level of the test animals was 0.31 ppm, with a maximum of 1.8 ppm. There was no PBB detected in the control animals.

Once on the experimental farm, all animals were separated into three groups according to their milk production level and stage of pregnancy. The groups consisted of: (1) high producers (40 lb milk per cow per day and above), (2) low producers (less than 40 lb milk per cow per day) and (3) dry animals.

Health and breeding records were maintained on each animal. Grain and forages were balanced nutritionally and fed in accordance with the level of production and stage of lactation. The composition and amounts of feeds fed to each group of animals was recorded and appears in Table 1. Daily milk records were maintained for each cow. The herd was also maintained on a DHIA testing program.

The animals were housed in barns containing free stalls and a loafing area. Forages were fed in outside, covered bunks. Grain was fed in one or more areas—the milking parlor, out of forage bunks, and from a magnetic feeder—depending upon the animals' level of milk production.

All calves were identified and tagged at birth. They were fed their dam's colostrum for the first three days after birth and housed in individual stalls in an insulated and ventilated calf barn. Calves were grouped in pens within the calf barn at one month of age. At three months the calves were moved to a noninsulated, ventilated barn. The calves' feeding program consisted of milk replacer, grain and forages at levels recommended for acceptable growth (Table 2).

**Table 2. Feed consumption—young animals.**

| Ingredients | Feed consumption of calves of various ages, lb/calf/day | | |
|---|---|---|---|
| | 1 month | 6 months | 12 months |
| Milk replacer | 0.75 | | |
| Dry feed[a] | 3.00 | 4.00 | 4.00 |
| Alfalfa hay | | 6.00 | 14.00 |
| Total | 3.75 | 10.00 | 18.00 |

[a] The dry feed consisted of a commercial 16% calf feed containing grain products, plant protein products, processed grain by-products, forage products, cane molasses, vitamins, and minerals.

The entire herd was placed upon a preventative herd health program pursuant to the recommendations of a local veterinarian and Michigan State University. Animals which died or became nonproductive were necropsied at Michigan State University.

## Results

The cows' milk production for the first year of the experiment is summarized in Table 3. Two months after initiation of the experiment, the test cows were producing 8.0 lb more milk per cow per day than the

**Table 3. Daily milk production by month of cows in assembled herd by origin.**

| | Control | | | | | | PBB | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average no. cows milking[a] | No. cows milking by trimester | | | Average milk/cow/ day, lbs | Accumulative average milk/cow/ day, lbs | Average no. cows milking[a] | No. cows milking by trimester | | | Average milk/cow/ day, lb | Accumulative average milk/cow/ day, lb |
| Month | | 1st | 2nd | 3rd | | | | 1st | 2nd | 3rd | | |
| October | 32.3 | 9 | 7 | 19 | 42.6 | | 28.7 | 7 | 7 | 18 | 48.6 | |
| November | 31.3 | 11 | 5 | 16 | 40.5 | 41.6 | 30.2 | 8 | 10 | 16 | 49.6 | 49.6 |
| December | 30.4 | 8 | 6 | 21 | 38.6 | 40.6 | 33.4 | 13 | 10 | 16 | 50.0 | 49.4 |
| January | 27.9 | 8 | 6 | 16 | 40.3 | 40.5 | 37.1 | 15 | 10 | 10 | 51.9 | 50.2 |
| February | 26.4 | 11 | 7 | 10 | 47.1 | 41.6 | 39.1 | 14 | 9 | 16 | 50.9 | 50.3 |
| March | 24.7 | 11 | 7 | 9 | 51.7 | 43.1 | 39.0 | 10 | 13 | 17 | 50.7 | 50.4 |
| April | 30.1 | 13 | 9 | 8 | 59.8 | 45.5 | 35.6 | 8 | 14 | 14 | 51.5 | 50.6 |
| May | 33.6 | 15 | 10 | 10 | 62.5 | 48.0 | 34.5 | 7 | 16 | 15 | 50.2 | 50.5 |
| June | 31.3 | 13 | 13 | 6 | 61.0 | 49.5 | 33.0 | 8 | 12 | 15 | 51.1 | 50.6 |
| July | 32.8 | 9 | 14 | 11 | 57.7 | 50.4 | 34.6 | 15 | 7 | 18 | 51.0 | 50.6 |
| August | 33.1 | 6 | 15 | 12 | 55.1 | 50.9 | 36.9 | 11 | 5 | 18 | 52.9 | 50.8 |

[a] Total milking days for all cows within each group divided by number days in respective month.

control cows. At the end of 12 months, the control cows were producing 2.2 lb more milk per cow per day than the test cows. The accumulative milk production for the test group and the control group was virtually identical at the end of 12 months. The mature equivalent milk production data prior to and during the experiment is summarized in Table 4.

**Table 4. Mature equivalent milk production of cows in assembled herd by origin.**

| | Origin | |
|---|---|---|
| | Control | PBB |
| Average age at initiation of experiment, mo. | 59.2 | 68.1 |
| Prior to experiment: | | |
| Number of lactations | 65 | 135 |
| Milk, lb | 15,757 | 14,819 |
| Butterfat, lb | 581 | 535 |
| End of 12 mo. | | |
| Number of lactations | 61 | 69 |
| Milk, lb | 16,383 | 16,246 |
| Butterfat, lb | 564 | 543 |
| Increase (decrease) | | |
| Milk, lb | 625 | 1,427 |
| Butterfat, lb | (17) | 8 |

[a] Mature equivalent record is defined as the amount of milk or fat that the same cow would have produced during the same lactation under the same environmental conditions had she been a mature cow.

The control cows' mature equivalent milk production was 15,757 lb at the initiation of the experiment, and test cows' mature equivalent was 14,819 lb. At 12 months, the control cows' mature equivalent had an increase of 625 lb to 16,383 lb. During the same 12-month period, the test cows' mature equivalent increased 1,427 lb, to 16,246 lb.

The body weight data for the test and control animals are summarized in Table 5. The weight gain for the two groups of animals was nearly identical—155 lb per control cow and 166 lb per test cow.

**Table 5. Body weight of cows in assembled herd by origin.**

| | Origin | |
|---|---|---|
| | Control | PBB |
| Average initial body weight, lb | 1365 | 1325 |
| Average body weight at 12 months lb | 1520 | 1491 |
| Average body weight gain, lb | 155 | 166 |

The reproduction and calf mortality data summarized in Table 6 indicate no significant ($p < 0.05$) differences between the two groups, although the number of services per conception was slightly higher for the test cows. None of the calves born alive have died. All are in good health and growing at a satisfactory rate.

**Table 6. Conception and calving of cows in assembled herd by origin.**

| | Origin | |
|---|---|---|
| | Control | PBB |
| No. animals | 40 | 43 |
| Total no. animals serviced[a] | 39 | 42 |
| Total no. services | 70 | 92 |
| Average no. services/conception | 1.79 | 2.14 |
| No. animals serviced only once to conceive | 19 | 20 |
| No. animals serviced only twice to conceive | 11 | 11 |
| No. animals serviced three or more times | 9 | 11 |
| Total no. abortions and stillbirths | 5 | 3 |
| Total no. calves born alive | 36 | 41 |
| Calf mortality | 0 | 0 |
| Calf deformities | 0 | 0 |

[a] Two animals (one from each group) were pregnant at time they entered herd and were never serviced at Research Farm.

The incidence of common dairy animal health problems summarized in Table 7 indicates no differences in the incidence of mastitis, milk fever, ketosis or metritis in the two groups of cows.

Table 7. Incidence of health abnormalities in cows in assembled herd by origin.

| Problem | Origin: Control | Origin: PBB |
|---|---|---|
| Mastitis[a] | 24 | 16 |
| Milk fever | 5 | 3 |
| Ketosis | 4 | 1 |
| Metritis | 4 | 5 |

[a] Number of treated cases or incidences.

Blood data are summarized in Tables 8 and 9. Blood collected from test animals prior to the initiation of the study showed significantly higher levels ($p < 0.05$) of calcium, phosphorus, total protein, albumin, lactic dehydrogenase, and creatinine and lower levels of thyroxine than blood taken from control animals at the initiation of the experiment. However, all mean values were within normal limits (David A. Morrow, Michigan State University; Jerry Stevens, University of Minnesota). Data from the blood samples collected at 8 months of the experiment indicated no significant ($p < 0.05$) difference in any parameter between the test and control animals. The 8-month blood means agreed with the initial means and were within normal ranges.

The necropsy data are summarized in Tables 10 and 11. Nine mature cows (five test and four control) and seven fetuses (two test and five control) were submitted to Michigan State University. Six of the adult cows (four test and two control) were alive when submitted. Three (one test and two control) had died on the farm.

Of the six live cows submitted for necropsy, three had been purchased for the express purpose of monitoring their health and thereafter submitting them to necropsy in order to observe the results of histopathological lesions observed. The remaining three live animals (one test and two control) were culled because of fertility problems.

One of the three adult cows (a control animal) submitted for necropsy died after an IV injection of a calcium solution was administered to treat a case of milk fever. The other two adult animals (one test and one control) died from acute mastitis during the heat of the summer.

The gross and microscopic lesions seen in the live adult animals which were posted were variable and without consistency, including pyelonephritis, pyometra and chronic mastitis, obesity and endometritis (one test and one control), chronic

Table 8. Initial blood parameters of cows in assembled herd by origin.

| Parameter[a] | Control: Mean | Control: S.D. | PBB: Mean | PBB: ± S.D. | $t$ Value[b] |
|---|---|---|---|---|---|
| No. animals | 38 | | 43 | | |
| Thyroxine, meq/100 ml | 5.4 | 1.1 | 4.1 | 1.3 | 4.9 |
| Glucose, mg/100 ml | 60.8 | 6.9 | 63.5 | 12.8 | 1.2 |
| Cholesterol, mg/100 ml | 176.9 | 42.8 | 168.0 | 41.3 | 0.9 |
| White blood count, $\times 10^6$ | 8.1 | 2.0 | 8.5 | 3.2 | 0.7 |
| Red blood count, $\times 10^6$ | 6.3 | 0.5 | 6.4 | 0.7 | 0.4 |
| Hemoglobin, g/100 ml | 11.0 | 1.1 | 11.3 | 1.3 | 1.0 |
| Hematocrit, % | 28.6 | 3.3 | 29.2 | 3.3 | 0.8 |
| Mean corpuscular volume, $\mu^3$ | 45.1 | 3.3 | 45.3 | 2.5 | 0.4 |
| Mean corpuscular hemoglobin, $\mu^3$ | 17.5 | 0.9 | 17.7 | 0.7 | 0.9 |
| Mean corpuscular hemoglobin concentration, % | 39.2 | 1.1 | 38.9 | 1.2 | 1.4 |
| Calcium, mg/100 ml | 9.3 | 0.5 | 9.9 | 0.5 | 0.6 |
| Phosphorus, mg/100 ml | 5.0 | 1.0 | 6.1 | 0.9 | 5.0 |
| Total protein, g/100 ml | 7.2 | 0.6 | 7.5 | 0.6 | 2.1 |
| Bilirubin, mg/100 ml | 0.3 | 0.1 | 0.3 | 0.1 | 1.7 |
| Alkaline phosphatase, U/ml | 14.6 | 4.9 | 16.0 | 6.5 | 1.1 |
| Blood urea, nitrogen, mg/100 ml | 14.7 | 2.9 | 13.6 | 2.9 | 1.7 |
| Uric acid, mg/100 ml | 1.2 | 0.2 | 1.2 | 0.2 | 0.4 |
| Albumin, g/100 ml | 2.1 | 0.3 | 2.4 | 0.2 | 4.1 |
| Globulin, g/100 ml | 5.0 | 0.4 | 5.1 | 0.7 | 0.5 |
| Albumin/globulin, ratio | 0.5 | 0.6 | 0.5 | 0.1 | 0.5 |
| Lactic dehydrogenase, U/ml | 505 | 37.7 | 540 | 45.6 | 3.8 |
| Serum glutamic oxalactic transaminase, U/ml | 62.7 | 10.8 | 58.8 | 7.8 | 1.9 |
| Creatinine, mg/100 ml | 1.0 | 0.1 | 1.1 | 0.2 | 2.9 |

[a] All analyses were of serum except PCP values.
[b] $t$ 0.05, 79 = 1.99; $t$ .01, 79 = 3.42.

**Table 9. Blood parameters of cows after 8 months in assembled herd by origin.**

| | Origin | | | | |
|---|---|---|---|---|---|
| | Control | | PBB | | |
| Parameter[a] | Mean | ± S.D. | Mean | ± S.D. | $t$ Value[b] |
| No. animals | 22 | | 19 | | |
| Glucose, mg/100 ml | 72.7 | 7.5 | 74.7 | 10.7 | 0.7 |
| Cholesterol, mg/100 ml | 200.3 | 75.3 | 227.5 | 67.0 | 1.2 |
| White blood count $\times 10^6$ | 7.1 | 2.6 | 7.5 | 2.0 | 0.6 |
| Red blood count $\times 10^6$ | 6.6 | 0.6 | 6.9 | 0.6 | 1.6 |
| Hemoglobin, g/100 ml | 12.4 | 1.2 | 12.7 | 1.1 | 0.8 |
| Hematocrit, % | 34.3 | 3.2 | 35.3 | 2.9 | 1.0 |
| Mean corpuscular volume, $\mu^3$ | 51.5 | 2.3 | 51.1 | 2.8 | 0.5 |
| Mean corpuscular hemoglobin, $\mu^3$ | 18.8 | 0.9 | 18.4 | 1.0 | 1.1 |
| Mean corpuscular hemoglobin concentration, % | 36.2 | 0.7 | 35.9 | 0.6 | 1.4 |
| Calcium, mg/100 ml | 10.0 | 0.5 | 10.1 | 0.4 | 0.4 |
| Phosphorus, mg/100 ml | 6.1 | 0.8 | 6.3 | 1.2 | 0.5 |
| Total protein, g/100 ml | 7.5 | 0.5 | 7.5 | 0.6 | 0.0 |
| Bilirubin, mg/100 ml | 0.4 | 0.1 | 0.4 | 0.1 | 1.3 |
| Blood urea nitrogen, mg/100 ml | 13.5 | 2.5 | 13.2 | 2.6 | 0.3 |
| Uric acid, mg/100 ml | 1.1 | 0.4 | 1.2 | 0.3 | 1.0 |
| Albumin, g/100 ml | 2.2 | 0.2 | 2.2 | 0.2 | 0.1 |
| Globulin, g/100 ml | 5.3 | 0.5 | 5.3 | 0.5 | 0.1 |
| Albumin/globulin, ratio | 0.4 | 0.1 | 0.4 | 0.1 | 0.8 |
| Lactic dehydrogenase, U/ml | 417 | 16.6 | 422 | 24.5 | 0.7 |
| Serum glutamic oxalactic transaminase, U/ml | 56.8 | 7.6 | 63.5 | 22.2 | 1.3 |

[a] All analyses were of serum except PCP values.
[b] $t$ 0.05, 39 = 1.69.

**Table 10. Summary of necropsy reports—adult cows.**

| | Origin | |
|---|---|---|
| Findings[a] | Control | PBB |
| Pyelonephritis | | 1 |
| Pyometra | | 2 |
| Fat cow syndrome | 1 | 2 |
| Endometritis | 2 | 1 |
| Abomasal ulceration | 1 | |
| Mastitis | 1 | 2 |
| Salmonellosis | | 1 |
| Enteritis | 1 | |
| Pneumonitis | 1 | |
| Myocardial failure | 1 | |
| Total animals submitted | 4 | 5 |

[a] One animal may have more than one finding.

**Table 11. Summary of necropsy reports—calves.**

| | Origin | |
|---|---|---|
| Findings[a] | Control | PBB |
| Dystocia | 2 | |
| Twin birth | 2 | |
| Abortion (unknown origin) | 1 | 1 |
| Stillborn (unknown cause) | 1 | 1 |
| Malformation, aortic valves | 1 | |
| Total calves submitted | 5 | 2 |

[a] One animal may have more than one finding.

abomasal ulcer and endometritis, chronic mastitis and degenerative arthritis, and chronic displaced abomasum.

The dead adult cows submitted for necropsy had suffered variable amounts of post-mortem decomposition. Diagnoses included acute mastitis and salmonellosis, acute mastitis, enteritis and pneumonia, and one animal that likely died as a consequence of calcium administered for milk fever. No pattern of gross histopathological lesions was seen in the test animals and their fetuses as compared with the control animals and their fetuses.